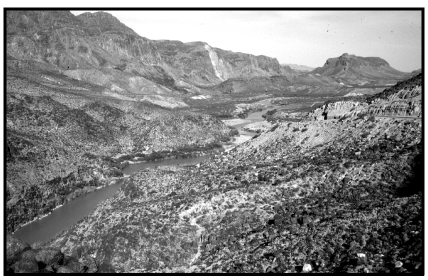
Background

North Texas: Canadian River



West Texas: Rio Grande

Central Texas: Little Blanco River

East Texas: Black Cypress Bayou

South Texas: West Mustang Creek

Background

Texas is the second-largest state in the United States, occupying about 7 percent of the total U.S. water and land area. Texas includes 267,277 square miles, of which 5,363 square miles are covered by water, ranking it first in the 48 contiguous states, followed by Minnesota (4,780 mi^2), Florida (4,683 mi^2), and Louisiana (4,153 mi^2). Groundwater resources are stored in nine major aquifers and 20 minor aquifers that underlie approximately 76 percent of state's surface area.

Texas population ranks second in the U.S., totaling 19,439,337 (1997) residents. The Texas population has shown steady growth from 1900 (3,480,710) to 2000 (20,231,000 estimated) (Figure 1) (TWDB, 1997). Using present moderate trends in growth, the Texas population is projected to nearly double, increasing to 36,671,000 by 2050. As the Texas population has continued to grow, pushing it to the second most populous state in the nation, the need to conserve, protect, and restore surface and groundwater supplies has never been more paramount.

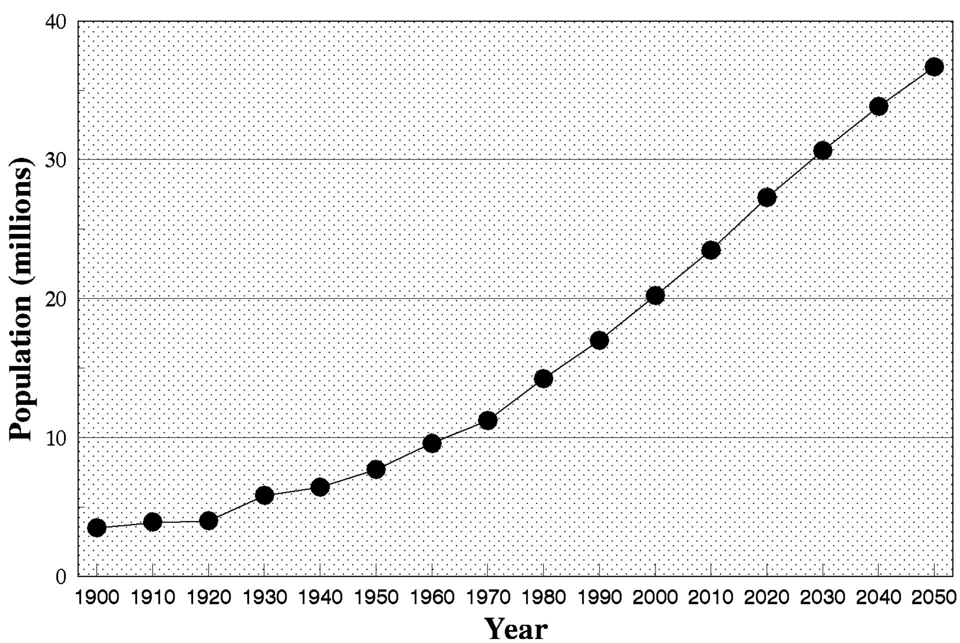


Figure 1. Historical and Projected Texas Population

Water is used for many purposes on a daily basis within the state. For example, in 1994 approximately 16.5 million acre-feet (ac-ft) of water was used by Texans (TWDB, 1997). Agricultural irrigation (11.0 million ac-ft; 67.0 %) was the largest use of water (Figure 2). Uses of water for municipal supplies (3.3 million ac-ft; 20.0 %) and industry (2.1 million ac-ft; 13.0 %) were also important. By year 2050, water use is expected to increase to approximately 18.4 million ac-ft, with major shifts in composition of water use forecasted. Agricultural use is expected to decline to about 46 percent (8.4 million ac-ft) by 2050, while municipal (34.0 %; 6.2 million ac-ft) and industrial use (20 %; 36.7 million ac-ft) are expected to increase.

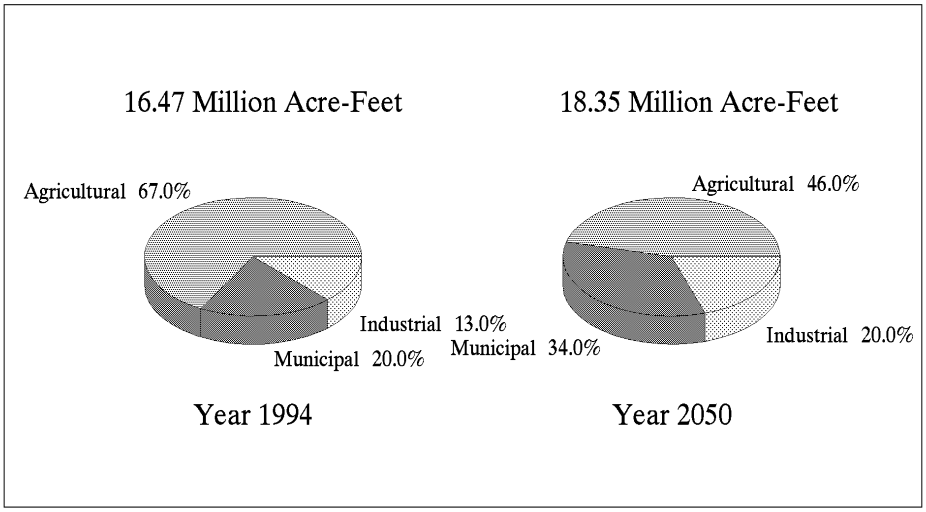


Figure 2. Composition of Texas Water Use in 1994 and 2050

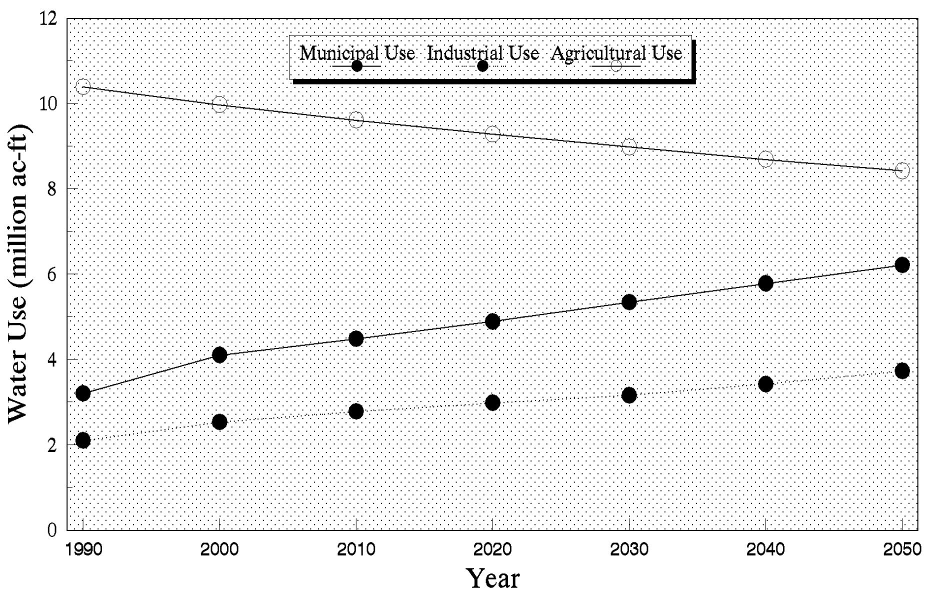


Figure 3. Projected Texas Municipal and Industrial Water Use.

In response to the growing Texas population, municipal and industrial water use in Texas is expected to steadily increase between 1990 and 2050 (Figure 3) (TWDB, 1997). Agricultural use is expected to decline over the this sixty-year time period due to: (1) improved irrigation management practices, (2) implementation of more efficient irrigation systems, (3) increased acreage set-aside for compliance with federal farm programs, and (4) decline in the number of farms.

On balance, statewide water use is anticipated to moderately increase by about 11 percent over the sixty year period. This overall increase in water use is due to significant increases in municipal and industrial uses, and includes a projected decline in water used for agricultural irrigation. As water use continues to increase in response to the growing population, the source of supply is also projected to change. In 1994, groundwater and surface water resources supplied about equal portions in meeting the state's water requirements (Figure 4). With decreasing availability of groundwater, through depletion over time, surface water is projected to meet about 69 percent of the State water needs by the year 2050, with groundwater declining to about 31 percent.

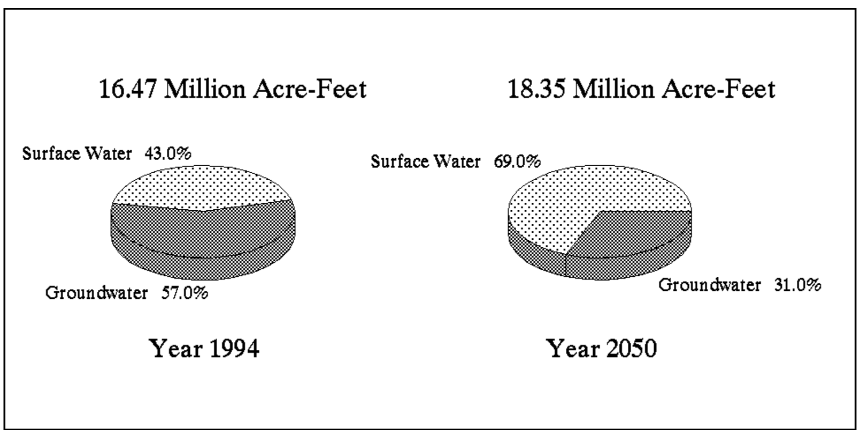
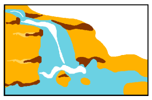


Figure 4. Composition Comparison of Water Supplies to Meet Uses, 1994 and 2050

Water quality management programs administered by the TNRCC have one basic goal, that of protecting and restoring Texas' surface and ground-water resources. The TSWQS provide the framework for accomplishing this goal. The TSWQS recognize the hydrologic and geologic diversity of the state by dividing major river basins (see map on the opening page of the Introduction section), reservoirs, and bays into defined segments. The TSWQS recognize 224 stream and river segments, 99 reservoir segments, 44 bay segments, and the Gulf of Mexico, which is treated as one segment (Table 1) (TNRCC, 1997a). All other streams and rivers, reservoirs, and estuaries are unclassified.



Rivers and Streams

Streams and rivers are characterized by flow. Perennial streams and rivers flow continuously, all year around. Intermittent streams and rivers become completely dry for a period of a week or longer during most years due to dry climatic conditions or upstream withdrawals. Some intermittent streams and rivers become completely dry in shallow portions of their channels, but maintain perennial pools in deeper areas. Many streams and rivers in Texas originate as intermittent streams that flow only following heavy rain showers. Others originate from abundant spring sources and are perennial.

Table 1. Atlas of Texas Surface Waters

State population (1997)	19,439,337
State land surface area (square miles)	261,914
State water surface area (square miles	5,363
Total number of river and stream miles	191,228
Number of intermittent stream miles (subset)	144,603
Number of perennial river miles (subset)	40,194
Number of ditches and canals (subset)	6,431
Number of border miles (subset)	2,475
Number of named streams and rivers	11,247
Number of named stream and river miles	80,000
Number of TNRCC classified stream and river segments	224
Number of TNRCC classified stream and river miles	14,348
Number of reservoirs (≥ 10 acres)	9,933
Number of total acres of reservoirs > 10 acres	1,994,600
Number of major reservoirs (> 5,000 ac-ft)	203
Total acres of major reservoirs	1,690,140
Total number of TNRCC classified reservoir segments	99
Total number of TNRCC classified reservoir acres	1,536,939
Square miles of bays	2,394
Square miles of TNRCC classified bays	1,990.7
Number of TNRCC classified bay segments	44
Square miles of TNRCC classified Gulf waters	3,879
Number of classified Gulf segments	1
Number of Gulf coastline miles	624
Acres of inland wetlands	6,471,012
Acres of coastal wetlands	1,648,400

* EPA RF3\DLG estimates

Pollutants discharged from municipal and industrial point sources or contained in diffuse nonpoint source runoff often directly affect the health of streams and rivers. Occurrence of depressed dissolved oxygen concentrations, elevated fecal coliform densities, and excessive nutrient loading are often associated with the discharge and assimilation of point and nonpoint pollutants in streams and rivers.

The health of streams and rivers is directly linked to habitat integrity instream, on the banks, along the riparian areas, and in adjacent wetlands. Stream quality may be altered if activities damage shoreline and wetland vegetation, which filter pollutants from runoff and bind soils. For example, riparian vegetation is often removed during channelization projects aimed at improving flow characteristics in streams and rivers. Removal of the vegetation eliminates shade that moderates stream temperature. Stream temperature, in turn, affects the availability of dissolved oxygen in the water column for fish and other aquatic life.

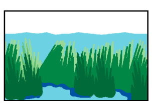
In order to accurately determine the magnitude and extent of the nation's total waters, the EPA has developed the river reach file and database. The computerized digital line graph and database reflect hydrologic features found on 1:100,000 scale USGS hydrologic maps. For instance, since 1990, the estimated number of Texas stream miles has increased from 80,000 to 191,228 due to improved resolution of map measurement techniques (Table 1).

Texas has approximately 191,228 miles of streams and rivers, with 2,475 miles forming portions of the borders with adjoining states and Mexico (Table 1). Some 11,247 Texas streams and rivers have been named; their combined length is approximately 80,000 miles. Of the total stream and river mileage, 144,603 miles (76%) typically have intermittent flow (stream channel becomes completely dry) in some portion of the water body for at least one week during most years. Approximately 40,194 miles (21%) of stream and river miles are perennial, meaning that they have sustained flow throughout the year. A small portion of stream and river miles (6,431 miles; 3.4 %) are canals and ditches. Most of the classified stream and river segments, which comprise 14,348 miles, have been established by the TNRCC on larger perennial water bodies. The mileage of classified streams and rivers accounts for about 36 percent of the total perennial miles.

Lakes, Reservoirs, and Ponds

Lakes, reservoirs and ponds are depressions that hold water for extended periods of time. These water bodies may receive water carrying pollutants from streams and rivers, runoff, direct discharges from domestic and industrial sources, and groundwater discharges. Pollutants become trapped in ponds, lakes, and reservoirs because relatively low current velocities, long storage times, and lack of shading by riparian canopy encourages uptake of dissolved materials by algae and bacteria, and their subsequent sedimentation, along with much of the particulate load delivered through tributary inflows. Therefore, they are especially vulnerable to additional pollutants from human activities in their watersheds. Even under natural conditions, sediment, nutrients, and organic materials accumulate in ponds, lakes, and reservoirs as part of a natural aging process called eutrophication. Unnatural sources of nutrients (such as point source domestic discharges and nonpoint source runoff) may overload lake and reservoir systems and accelerate eutrophication. Excessive growths of algae and macrophytes, depressed dissolved oxygen concentrations, and elevated pH values are often symptoms of eutrophication from anthropogenic sources.

Texas has approximately 9,933 reservoirs and lakes that cover 10 surface acres or more. Collectively, these reservoirs and lakes cover approximately 1,994,600 acres. Major reservoirs having more than a 5,000-acre-foot capacity number 203 and together cover approximately 1,690,140 acres (Table 1). The TNRCC has established 99 reservoirs as classified segments; their surface acreage accounts for about 91 percent of the total acreage for major reservoirs and about 77 percent of the acreage for all reservoirs and lakes.



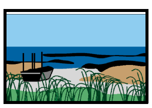
Estuaries

Estuaries are coastal waters where inflowing stream or river water mixes with, and measurably dilutes, sea water. In Texas, estuaries are the lower tidal portions of rivers and streams that directly enter the Gulf of Mexico or its bay systems. For this report, tidal portions of streams and rivers, although estuaries, are considered part of the stream and rivers category. Tidal streams and rivers are usually confined by stream banks and they are characterized in miles rather than area (square miles).

Estuaries serve as important nursery areas for many commercial fish and most shellfish populations, including shrimp, oysters, crabs, and scallops. The Texas fish and shellfish industry relies on productive estuarine waters and their adjacent coastal wetlands to provide healthy habitat for important life stages of fish and shellfish development. Recreational anglers also enjoy harvesting fish that reproduce or feed in estuaries, such as red drum, spotted seatrout, and flounder.

Pollutants from both local and distant sources tend to accumulate in estuaries. Most pollutants that enter streams and rivers eventually migrate toward the coast. As rivers approach the coast, their mouths broaden and stream velocity decreases. The reduction in stream velocity and fluctuation of tides from the Gulf reduce flushing and entrap nutrients and pollutants at the head of estuarine waters. This natural trapping process establishes the basis for highly productive estuarine ecosystems, but also makes estuaries vulnerable to excessive pollutant loading from point and non-point sources.

Historical development patterns along the Texas coast have amplified natural trapping functions and overloaded the estuaries. Industrial development and population centers have clustered around estuaries and bays with access to shipping and barge transport. Adjacent water bodies are used for waste disposal. The Galveston Bay Estuaries Program and Coastal Bend Bays and Estuaries Program were created by the TNRCC and EPA to address a wide array of problems (for example, contaminated sediment, nutrient enrichment, depressed dissolved oxygen concentrations, and declining fish, shellfish, and sea grass populations) and develop management strategies to deal with them. Texas has 2,394 square miles of bays and estuaries (Diener, 1975) (Table 1). Forty-four bay systems have been classified by the TNRCC. Classified bays cover approximately 1,990.7 square miles and account for about 83 percent of all the bay and estuary area.

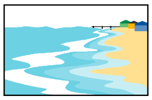


Wetlands

Wetlands are generally considered as a transition zone between land and water where the soil is occasionally or permanently saturated with water. In Texas, there are approximately 6,471,012 acres (10,108 mi^2) of inland wetlands and 1,648,400 acres (2,575 mi^2) of coastal (saltwater) wetlands (Table 1). Wetlands are populated with plants that are specially adapted to grow in standing water or saturated soils. There are many different types of wetlands, including marshes, bogs, swamps, mangroves, prairie playas, and bottomland hardwood forests. Wetlands may not always appear to be wet. Many wetlands dry out for extended periods of time. Other wetlands may appear dry on the surface but are saturated with water beneath the surface.

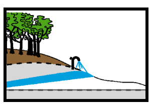
Saltwater wetlands fringe estuaries; freshwater wetlands border streams, rivers, and reservoirs or occur in isolation. Generally, wetlands improve water quality, provide critical habitat for a wide variety of fish and wildlife, provide storage for flood waters, and stabilize shorelines. Wetlands filter nutrient and sediment from water before it enters adjacent water bodies and underlying groundwater aquifers.

Wetlands can be physically destroyed by filling, draining, and dewatering. Wetlands can also be damaged by the same pollutants that degrade other water bodies, such as nutrients, toxic substances, and oxygen demanding wastes.



Ocean Shoreline Waters

Gulf of Mexico shoreline waters in Texas provide critical habitat for various life stages of commercial fish and shellfish (such as shrimp), provide habitat for endangered species (such as sea turtles) and support popular recreational activities, including sport fishing, swimming, surfing, and boating. The Gulf of Mexico encompasses an area of approximately 3,879 square miles within Texas' jurisdiction, from Sabine Pass on the north to Brazos Santiago Pass on the south (Table 1). About 624 miles of the Gulf form the Texas coastal shoreline. Despite its vast size and volume, the Gulf of Mexico is vulnerable to impacts from pollutants, especially in the nearshore waters that receive inputs from treated domestic and industrial waste discharges, adjoining water bodies, and offshore dumping. Oil spills from tankers or offshore drilling facilities may also generate persistent adverse impacts on the shoreline of the Gulf.



Ground Water

Beneath the land's surface, water resides in two general zones, the saturated zone and the unsaturated zone (Figure 5). The unsaturated zone lies directly beneath the land surface, where air and water fill the spaces between soil and rock particles. Water saturates the pore spaces in the saturated zone, which lies beneath the unsaturated zone in most cases. The term "groundwater" applies to water in the saturated zone. Surface water replenishes (or recharges) groundwater by percolating through the unsaturated zone. Therefore, the unsaturated zone plays an important role in groundwater hydrology and may act as a pathway for groundwater contamination.

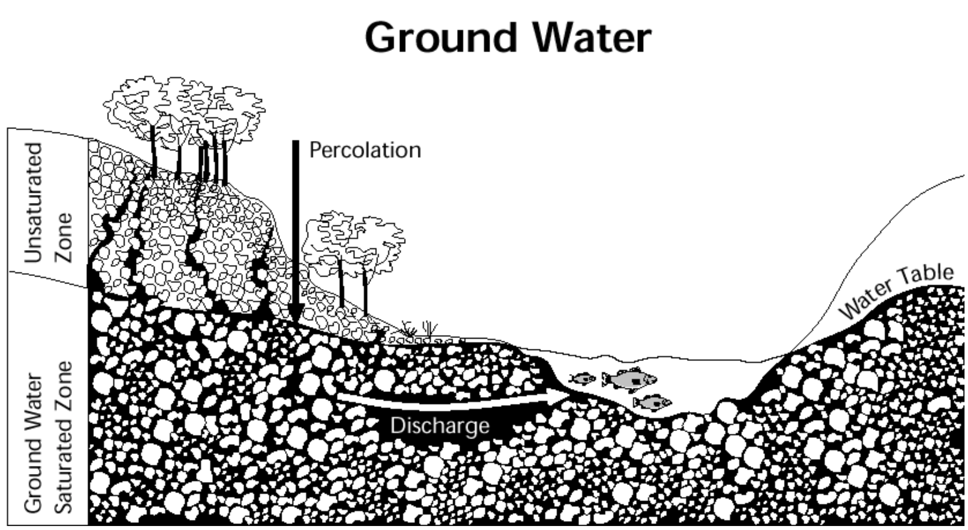


Figure 5. Groundwater Schematic

Texas Climatic and Geographic Diversity

The Texas terrain and climate are highly variable among different regions of the state. The eastern third of the state experiences high relative humidity, abundant rainfall, warm to hot summers, and mild, wet winters. The middle third of the state typically has moderate humidity, moderate amounts of precipitation, hot summers, and dry winters. The western third of Texas is characterized by low relative humidity, episodic rainfall, hot, dry summers, and mild, dry winters. The rainfall distribution ranges from an average of eight inches per year in the desert mountains in the western portion of the state to an average of 56 inches annually in the coastal plains and coniferous forests in the east (TWDB, 1997). Land forms in northern and southern areas are similar, ranging from the flat, treeless high plains in the panhandle region, where rainfall averages about 20 inches per year, to the flat lower Rio Grande Valley, where annual rainfall is typically less than 25 inches per year.

Omernik and Gallant (1987) developed a Texas map that identifies 12 distinct ecoregions based on similarities in land use, land surface form, potential natural vegetation, and soils (Figure 6). Because of its diversity in mapped features, Texas has more distinct ecoregions than any other state. The map is based on the presumption that streams and rivers derive their character primarily from the watersheds they drain. One only needs to travel across Texas from east to west along IH-10 to realize distinct spatial differences in land form, soil types, natural vegetation, climate, and land uses. The Piney Woods of East Texas slowly transform to the Post Oak and Blackland Prairie areas, where richer, deeper soils promote agricultural activities. In sharp contrast to these areas, farther west one finds the rolling, rough topography and thin rocky soils of the Edwards Plateau. The Trans-Pecos area of Far West Texas, with its arid climate and harsh terrain, produces only sparse, drought-resistant vegetation without irrigation.

Streams that cross these natural areas, and the reservoirs found within them, are just as distinct (photographs of some examples are shown on the opening page of this section). As water flows over and through the land to the stream channels, it acquires and integrates characteristics from the land, especially from its soils, topography, and vegetation. The bayous and sloughs of the Piney Woods typically have a sluggish flow due to low stream gradients, and are highly-colored dark brown to black due to abundant natural organic matter. The streams that traverse the Post Oak and Blackland Prairie areas, while faster flowing, tend to carry higher suspended inorganic sediment loads due to the erosion of deep soils. The rocky terrain of the Hill Country tends to produce fast-flowing, clear streams due to high stream gradients and thin soils. As a result of the arid West Texas climate, few streams cross the Trans-Pecos area; those that do resemble the Hill Country streams, but often have sandy bottoms and high salt content due to high evaporation rates and flow over salt-bearing strata. The streams of the high plains and Gulf coastal plains typically have low stream gradients, sandy bottoms, and shallow water that spreads out over wide stream channels.

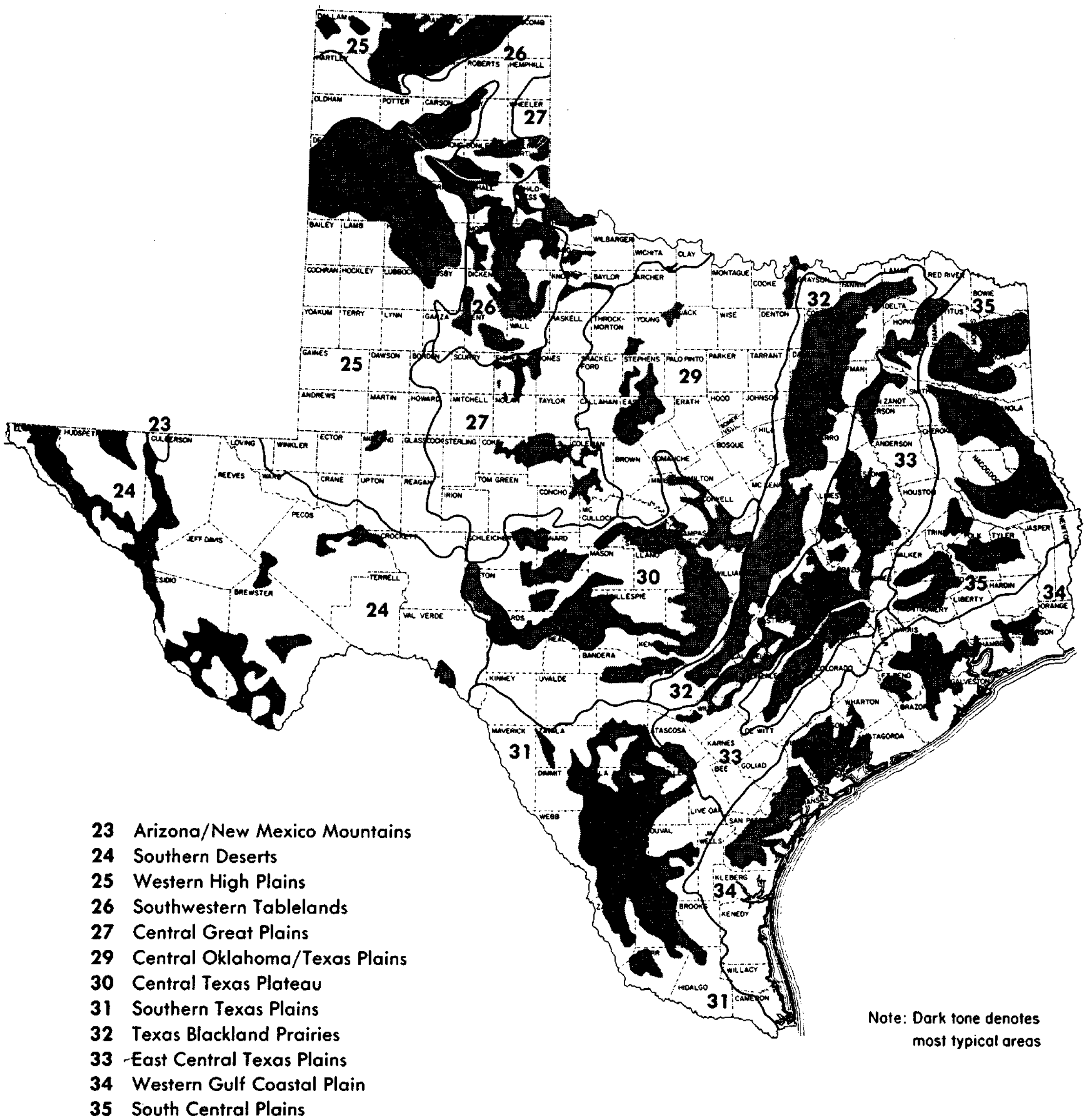


Figure 6. Texas Ecoregion Map